The Design and Installation of Solar Pumping System for Pond Aeration in the Mina Makmur Fish Cultivator Group at Desa Ringinharjo, Bantul

Muhammad Nadjib[1*], *Fitroh* Anugrah Kusuma Yudha[1], *Aditya* Kurniawan[1], *Mujiyana*[1], *Nur* Ardiyansyah[1], and *Teguh* Wibowo[2]

[1]Mechanical Engineering Department, 55183 Universitas Muhammadiyah Yogyakarta, Indonesia
[2]Mechanical Engineering Department, 55282 Institut Teknologi Kedirgantaraan Adisutjipto, Indonesia

Abstract. The fish cultivator group "Mina Makmur" manages tilapia nursery ponds. The group faced a problem, namely: the growth of fish fingerlings was not assuring, and their bodies looked weak. This phenomenon is assumed to be due to poor pool water quality, which affects the lack of oxygen. The solution given is that the fishponds require an aerator. The solar-powered aerator was a choice to minimize operational costs. This paper aimed to design and install a solar pumping system as an aerator in a fishpond. The design begins with a site survey. A water pump was selected based on survey results. The solar module was designed using the current concept. The result of the design of the solar pumping system was that it requires a DC water pump with a power of 26.4 W and a solar module with a capacity of 60 Wp. The solar module was installed in a location free of shade and as close to the pump as possible, and the pump was placed outside the pond. These designed and installed solar pumping systems were functioning correctly. The resulting water discharge was 3.03 liters/minute at an average solar irradiance of 795.46 W/m^2.

1 Introduction

The fish cultivator group "Mina Makmur" is in Deresan RT 08, Ringinharjo, Bantul, Yogyakarta. This group stands as a community effort to survive the economic impact of the COVID-19 pandemic. There are 14 members of the "Mina Makmur" group. This group has 14 fishponds, which are in the rice fields. The pool size varies from 2 m x 1.5 m, 4 m x 5 m, and 5 m x 7 m. The group-reared tilapia consists of breeding and rearing. The group's efforts are successful. It is proven that after running for almost two years, this group still exists. So far, group members feel that raising tilapia can be used as an alternative source of income that can support their daily lives.

* Corresponding author: nadjibar@umy.ac.id

Along with time, the group faces problems in managing fish farming. About a year ago, group members were entirely shocked by the condition of tilapia fingerlings in the pond. The growth of the fish looked unnatural, and its physical condition was weak. The group conducted long discussions both internally and externally to overcome this situation. The discussion concluded that this incident was suspected to be due to the effect of pond water quality. The group took the step to increase the frequency of changing pool water. However, this effort has not produced optimal results because the condition of the fish fry was still the same as before, even though it had decreased. The group's fishpond area is presented in Fig. 1.

Fig. 1. Fishpond belonging to the group "Mina Makmur".

The group's assumption about the cause of the pond's condition is correct. The pond ecological conditions for fish development are influenced by water quality parameters, such as dissolved oxygen, ammonia-nitrogen ratio, alkalinity, CO_2-free, water hardness, and planktonic life [1]. In this case, oxygen in fishponds is necessary to maintain fish survival [2]. The need for oxygen increases with the number and growth of fish. The success of fish farming is influenced by the manager's ability to maintain or overcome water quality. One of the determining factors for pond quality is the dissolved oxygen (DO) content. Lack of DO concentration in pond water is the main reason for the low yield of fish farming [3]. DO has significance to the organisms being cultured and affects the chemical index of water and the biological population in ponds [4]. Low DO can cause fish stress, be susceptible to disease transmission, reduce fish growth rates, and extreme conditions can cause fish to die [5]. These conditions can reduce the level of productivity of fish nurseries. Increasing DO is to apply aeration techniques in ponds [6]. Aeration is the process of adding oxygen to water until the oxygen is dissolved so that the oxygen concentration in the water increases. Aerators impact the oxygen transfer rate from air to water by increasing turbulence and the surface area of water in contact with air [7]. Therefore, the aerator can be used as a solution to overcome the problems in this group.

The installation of aerators in group fishponds faces obstacles in terms of providing energy resources. The pond is far enough from the residential area. In addition, using PLN electricity for the aerator can be a burden for the group in terms of operational costs. For this problem, the right solution is to build a pond aeration system using energy from the sun.

Solar energy is abundantly available in Indonesia since the area is located on the equator. The average solar radiation in Indonesia is 4.8 $kWh/m^2/day$ [8]. This enormous potential of solar energy can be utilized as a source of energy for human needs. Solar energy as a renewable energy source has advantageous characteristics: as long as life exists in nature, it will continue without depletion; it is found anywhere on earth, has clean energy, and is environmentally friendly [9]. Solar energy utilization requires human intervention in the field of photons and heat [10]. Photons resulting from fusion reactions in the sun can be converted into electrical energy directly through solar modules known as photovoltaic (PV) technology. Solar energy can also be converted into thermal energy for the process of heating substances or can be converted to produce electrical energy. Applying photovoltaic technology is directly beneficial as electricity is needed in everyday life. PV technology can be categorized as stand-alone systems, PV systems for solar vehicles, grid connection PV systems, and PV systems for buildings [11]. PV technology applications in the stand-alone category include solar home systems, streetlights, communication systems, refrigeration, and pumping systems. Solar pumping systems (SPS) primarily provide domestic-scale water supply, animal husbandry, irrigation in remote areas, and fisheries [12].

This paper aims to design and install a solar pumping system for aeration in tilapia nursery ponds in the "Mina Makmur" fish cultivator group. Applying a solar pumping system for aeration is expected to help groups so that tilapia cultivation takes place optimally with the lowest possible operational costs.

2 Methodology

SPS is classified into several types based on their components, as shown in Fig. 2. The selection of the SPS type is adjusted to field conditions, technical aspects, and operational considerations.

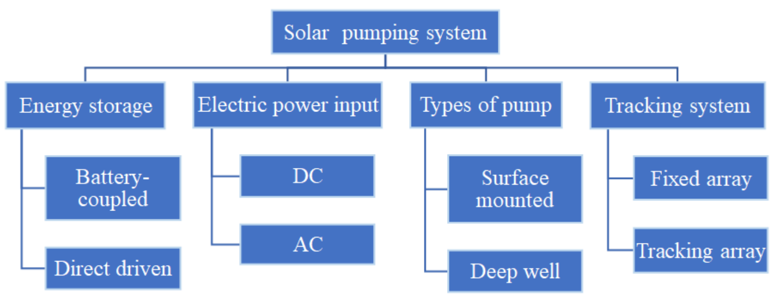


Fig. 2. Classification of SPS [13].

The considerations in designing SPS for tilapia pond aeration in this group were as follows.

1. SPS was planned not to use batteries, so the solar module power directly drove the pump. This selection was made considering a small-scale aeration system and the operational costs of the battery. The battery was one of the most expensive components in a PV system [14].
2. This aeration system was small-scale because it only served one fishpond, so SPS was more efficient when using DC electricity.
3. The depth of the nursery pond was one meter. The pool walls were above the ground level. Therefore, the pump was placed above the lip of the pond wall to facilitate maintenance.
4. Solar modules were installed permanently in the frame because the solar insolation in this region is relatively high [8].

Based on Fig. 1 and the above considerations, the selected SPS were directly driven, DC systems, surface mounted, and fixed modules. The SPS plan drawing for fishpond aeration is shown in Fig. 3. The planned aerator system comprised solar modules, module poles, switch panels, wiring, and water pumps. The solar energy that hit the solar module was directly converted into DC electrical energy. The electrical power drove the pump motor and rotated the pump impeller. The pressure difference between the inlet and outlet sides around the pump caused the water in the pool to rise and exit through the pump outlet. This aerator system required a water pump and solar module design.

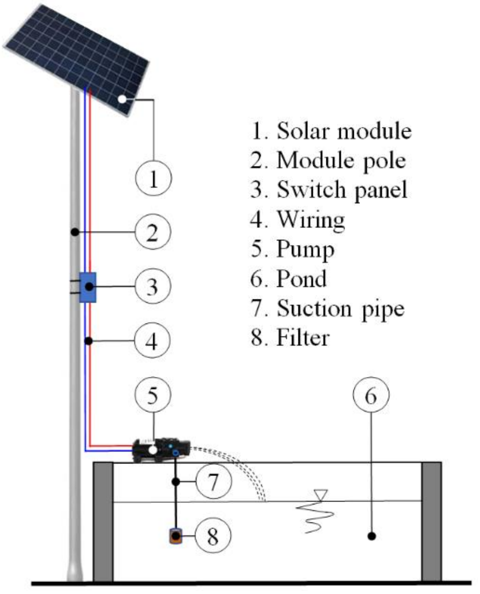


Fig. 3. Scheme of solar aerator installation.

The SPS design and installation steps are shown in Fig. 4. The first step is to design the water pump. Pump design requires existing fishpond data, including pond size and water level. The data is used to determine pump selection. The second step is to design the solar module. The main parameters are the pump voltage and current, which are used to estimate the daily load. Then, the charge:load (C:L) ratio is determined. This parameter is the ratio between supply and load energy. Peak sun hour (PSH) is determined based on the sun's insolation at the location. PSH is the length of adequate sunlight per day. The minimum module current must be provided based on the daily load, C:L ratio, and PSH. The minimum current data determines the appropriate solar module on the market. The electric current at the maximum power of the solar module must be higher than the minimum current from the calculation results. The third step is the installation of SPS on site. The equipment installed is the pole and frame of the solar module, the solar module and its wiring system, and the water pump. The third step ends with field testing to ensure the SPS functions correctly. Parameters tested include solar irradiance, solar module voltage and current, and water flow rate generated by the pump. The data obtained are plotted in a graph and analyzed. The resulting graph shows the evolution of radiation, module power, and water flow rate. The analysis is continued by determining the efficiency of the solar module.

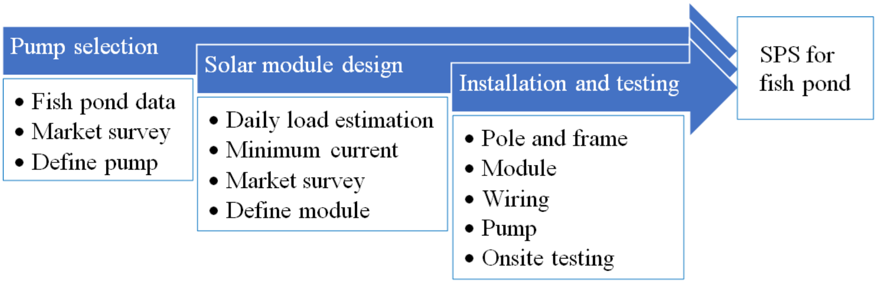


Fig. 4. SPS design and installation steps.

3 Results and Discussion

3.1 Water pump selection

Based on field surveys, it is known that the size of the fishpond is 4 m x 5 m x 1 m. The height between the pool water's surface and the pool wall's lip is 50 cm. Given the small water lift height, a DC pump product from Mollar was chosen with the technical specifications, as shown in Table 1.

Table 1. Technical specification of the water pump.

Description	Value
Voltage	DC 12 V
Ampere	2.2 A
Flow rate	4 LPM
Pressure	100 Psi

The technical specifications in Table 1 that are a concern for designing pump power sources are voltage and current. The pump's power source is a solar module, so the voltage must be 12 V DC. The pump power, according to the parameters in Table 1, is 26.4 W.

3.2 Solar module design

The solar module design is a stage that determines the system's reliability. The solar module is an expensive PV system component [14], so it must be designed properly to produce the correct specifications. Solar module design for SPS uses the current method to avoid undersized designs [15, 16]. This method determines the specifications of the solar module by using electric current calculation.

The daily load was calculated by multiplying the pump's nominal current and the active pump's duration, producing optimal discharge. This multiplication results in the number of ampere-hours per day, which is the energy capacity of the load per day. The assumption was that the water pump would remain operational for 5 hours. The number of ampere-hours obtained was 11 ampere-hours/day. This energy capacity was obtained based on the load component (pump). To find out the actual daily load requirement, namely the energy that the solar module must provide, the daily load was multiplied by the C:L ratio. The value of the C:L ratio is 1.3 [15]. This design chose a C:L ratio of 1.1 [17] because the PV system was categorized as simple, without batteries and a solar charge regulator, so the electricity losses were low. The calculated actual daily load was 12.1 ampere-hour/day.

Yogyakarta has an average solar radiation of 4.5 kWh/m^2/day [18]. The average solar radiation at the earth's surface is 1000 W/m^2 [19]. The PSH value is the solar insolation divided by the irradiation on the earth's surface or 4.5 hours. The daily load divided by PSH produced the minimum current that must be provided (= 2.69 A). This minimum current was used as the basis for selecting solar modules. A market survey was conducted to select solar modules according to the calculation results. Solar module products with a higher current at maximum power (Imp) and closer to the minimum current were selected. The solar module was selected from Maysun Solar products with an Imp of 2.73 A and a maximum power of 60 Wp. The solar module calculation steps are presented in Table 2. The technical specifications for the solar module are given in Table 3.

Table 2. Resume of solar module calculation.

I. Daily load estimation			
Description	**Current (A)**	**Time (hour)**	**Ampere-hour/day**
Pump 12 V	2.2	5	11
II. Solar module design			
C:L ratio			1.1
Actual daily load (ampere-hour/day)			12.1
PSH (hour)			4.5
Minimum current (ampere)			2.69
Selected Imp of solar module (ampere)			2.73

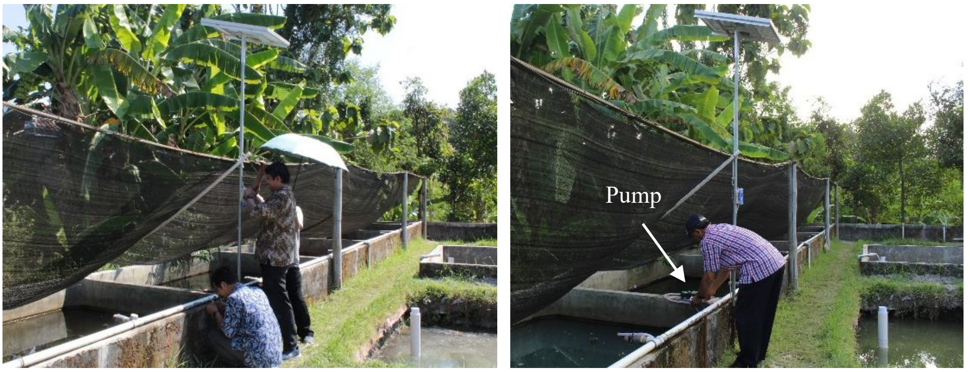
Table 3. Technical specification of the solar module.

Description	**Value**
Rated maximum power	60 Wp
Voltage at Pmax	18.76 V
Current at Pmax	2.73 A
Open-circuit voltage	20.86 V
Short-circuit current	3.05 A
Operating temperature	Up to 85°C

3.3 Installation

The SPS installation began with connecting the cable to the solar module terminal. The solar module was placed on the frame that had been prepared. The solar module frame was made of galvanized iron elbow with 30 mm x 30 mm dimensions. The solar module was installed facing north with a tilt angle of 15° [20]. The choice of direction and angle is intended to optimize the acquisition of solar energy throughout the year. The pole, with its diameter and height of 1.25 inches and 3 m, respectively, was installed with solar modules and frames. The pole material was galvanized iron. The pole was buried in the ground to a depth of 30 cm. The selection of pole height was carried out to facilitate the maintenance of solar modules. The pole was placed as close to the pool as possible to minimize electrical losses.

The pump was placed on the lip of the fishpond by fastening it using a planting bolt. The threaded hose was used as a suction and discharge line. The end of the suction line was fitted with a filter to keep the pump clean from pool dirt. After that, the pump cable was connected to the cable from the solar module. A switch panel was installed between the solar module and the pump to facilitate SPS maintenance. The documentation of SPS installation is presented in Fig. 5.5.



(a) (b)

Fig. 5. Installation of SPS: (a) solar module and pole, (b) water pump

3.4 Field Trial of SPS

The purpose of conducting field trials of SPS is to ensure that the aerator pond functions as it should. The data collection on solar radiation intensity, solar module voltage and current, and pump water flow rate were simultaneously carried out at any time. The tools used in field trials were a solar power meter, a multi-tester, and a flow meter. The results of field trials are shown in Figure 6.

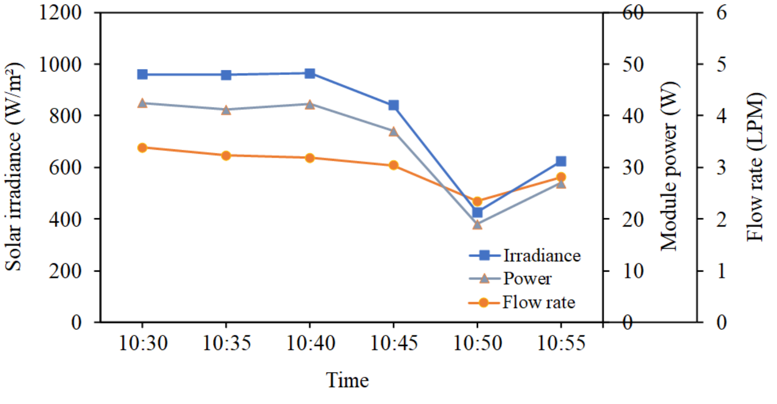


Fig. 6. Field test results.

The field trials were carried out under fluctuating weather conditions. In the beginning, the intensity of solar radiation was high enough, with the highest value of 963.25 W/m^2. The radiation intensity started to decrease at 10:40, with the lowest value of 427.18 W/m^2 at 10:50. The cause of fluctuating solar radiation was the influence of natural conditions such as clouds, water vapor, dust, and aerosols in the atmosphere. The fluctuating solar radiation intensity automatically causes solar module power and water flow rates to change. The average solar irradiance, solar module power, and water flow rate obtained during field trials were 795.46 W/m^2, 34.82 W, and 3.03 liters/minute, respectively. Based on the solar radiation that hit the solar module with an area of 0.39 m^2 and the power generated, it is known that the average electrical efficiency of the solar module was 11.17%. The efficiency outcome is favorable as it falls within the range of 10-20% for solar panels used in domestic applications [21]. Thus, the SPS that had been installed was functioning correctly, which was indicated by the solar module that was able to produce electrical energy, and the water pump was able to lift water from the pond so that it acted as an aerator.

4 Conclusion

The community service in the "Mina Makmur" fishpond group has been completed. The activities were designing, installing, and testing a solar pumping system for aerators. The conclusions of this activity are as follows.

1. The selected water pump is a DC surface-mounted type. The pump's voltage and nominal current are 12 V and 2.2 A, respectively. The solar module used has a rated maximum power, voltage at maximum power, and current at the maximum power of 60 Wp, 18.76 V, and 2.73 A, respectively.
2. The installation of SPS follows the planning design. The field test proves that the SPS is functioning correctly. The average electrical efficiency of the solar module is 11.17%. The average water flow rate is 3.03 liters/minute at the average solar irradiance of 795.46 W/m^2.
3. SPS for this aerator is very beneficial for fish cultivating because it can prevent DO shortages, the method of operating the equipment is easy, and the operational costs are meager. However, this tool requires routine maintenance, especially on solar modules, so its performance is optimal and has a long lifetime.
4. This aeration system can be developed to serve other fish ponds according to field needs.

5 Acknowledgments

The authors would like to thank the parties who helped carry out this activity, specifically Lembaga Pengabdian Masyarakat Universitas Muhammadiyah Yogyakarta and the "Mina Makmur" fish cultivator group.

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